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Evaluation of occupational and medical dose on interventional cardiology procedures by Monte Carlo method

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A cardiologia intervencionista é um conjunto de procedimentos médicos que tem como principal foco diagnosticar e tratar pacientes com problemas cardiovasculares. Embora o uso dos raios X neste caso seja justificado, é de grande importância fazer uma avaliação das doses tanto nos pacientes quanto nos profissionais envolvidos, pois as doses podem ser altas, uma vez que, na maioria dos casos, os procedimentos são demorados e complexos. O objetivo deste trabalho é estimar a dose de radiação numa paciente e em uma médica através de coeficiente de conversão de dose (CCs) equivalente (H) e efetiva (E) durante exame de angiografia coronária. Os CCs de dose foram simulados através do código Visual Monte Carlo (VMC) e uma dupla de simuladores antropomórficos voxel (Female Adult voXel). Os CCs de dose foram normalizados em termos do produto kerma-área (KAP). Como esperado, para todas as situações estudadas, a projeção anteroposterior (AP) apresentou os maiores valores de CCs de dose equivalente e dose efetiva para a paciente.
Palavras-chave: Dosimetria; proteção radiológica; Visual Monte Carlo

Interventional cardiology consists on a set of medical procedures which are mainly focused on diagnosing and treating patients who suffer cardiovascular diseases. Even though the usage of X-ray is justified on this case, it is greatly advised to evaluate the dose which professionals and patients will be exposed due to the fact that the complexity and length of the procedures often require high doses. The objective of this work is to estimate the radiation dose on both a patient and a physician through conversion coefficient (CCs) of effective dose (E) and equivalent dose (H) during a coronary angiography examination.The dose CCs was estimated using the Visual Monte Carlo code (VMC) and a pair of simulators anthropomorphic voxel (Female Adult VoXel). The CCs were normalized in terms of kerma-area product (KAP). As expected, for all situations studied, the patient in anteroposterior projection (AP) obtained the highest conversion coefficient of equivalent dose and effective dose.
Key-words: Dosimetry; radiological protection; Visual Monte Carlo

1. INTRODUCTION

Interventional radiology (IR) is a branch of medicine which is consisted on a series of medical procedures focused on the diagnosis and healing pathologies of some organs and tissues of the human body. Among the organs diagnosed by this kind of procedure, the heart is one of the most studied, being the coronary angiography one of the most performed examinations [1, 2, 3]. The physician can visualize radiographic images on monitor through the use of a catheter and a radiopaque substance which are guided via percutaneous tissue to the region of interest. This process is generally lengthy and requires a large number of images; therefore, patients as well as the medical teams can be exposed to very high dose, which could increase the risk of stochastic and deterministic effects [4, 5, 6].To evaluate this risk, the measurement of the effective dose and equivalent dose is usually made. One method of obtaining those dosimetric quantities is to determine the absorbed dose in each organ and tissue accurately. However, this process is relatively complicated to be performed; in certain cases, its application becomes even impossible. What can be done is to estimate, using a code which simulates the transport of the radiation, the absorbed dose on the organs and tissues by the Monte Carlo method (MC) and consequently determinate the conversion coefficients (CCs) normalized to a dosimetric quantity directly measurable [8].

Radiological protection international institutions recommend the calculation or simulation of CCs dose to conventional radiological procedures. However, for complex procedures such as interventional radiology (IR), there is no publications in specific dose conversion coefficient.

The dose CCs published by the international norms are not appropriate for calculating the effective dose for IR, because the irradiated field sizes and beam quality used differ from those used in IR. Therefore, regarding the radiological protection scope, there is a need for systematic dose CCs tables which could allow the effective and equivalent dose estimative to procedures in IR. In this sense, this work is mainly focused on estimating the radiation level to which a patient and a physician are exposed through effective and equivalent dose CCs normalized the kerma-area product (KAP).

2. MATERIALS AND METHODS

2.1 Patient and physician irradiation scenario

On this work, the CCs calculations were estimated using the radiation transport code Visual Monte Carlo (VMC) [9]. A pair of anthropomorphic voxel phantoms represented by an adult female was introduced in this code. The FAX (Female Adult voXel) [10] is an anthropomorphic voxel phantom developed on the Federal University of Pernambuco and based on an image bank of a woman with a similar anatomy to the one who is the reference for the International Commission on Radiological Protection [11]. On this study, the CCs were obtained in an extreme procedure situation. In other words, situations where the physician was not using individual protection equipments, for example, plumbiferous apron and thyroid protector. The pair of simulators was inserted in a virtual scenario separated by 7 cm from one another, simulating the real distance from the physician to the patient subjected to the coronary angiography examination. Figure 1 depicts the simulation scenario composed by the physician (standing) and the patient (lying).

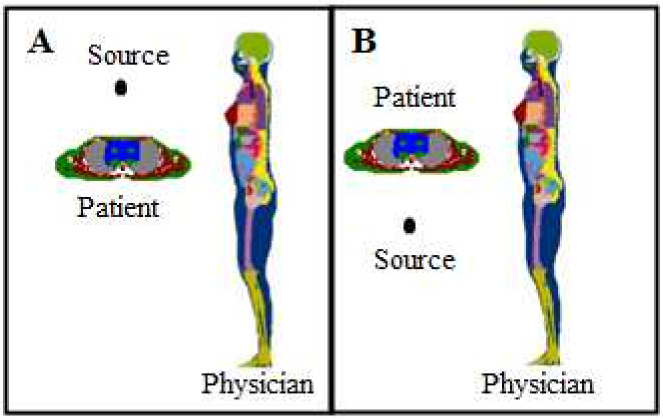

Figure 1. Pair of anthropomorphic voxel phantoms representing the patient (lying) and the physician (standing) as well as a source of radiation on projections AP (A) and PA (B).

A source of X rays emit photons in a solid angle (cone way) was used, covering a circular area of 132 cm² of the chest region of the patient in both projections anteroposterior (AP) and posteroanterior (PA) as presented on figure 1.

2.2 Simulation of X-ray spectrum

The X-rays spectrum was obtained using the software Specgen [12] along with the most used radiographic parameters on the clinical practice of the coronary angiography examination. The main parameters used in the simulation were anode angle of 17º, beam filtration of 2.5 mmAl, voltage and current-time in the tube of 70 kV and 1mAs, respectively, and two irradiation geometries (AP and PA). KAP was obtained by multiplying simulated air kerma (K_{ar}) by the area of the irradiated field.

2. RESULTS AND DISCUSSIONS

The equivalent and effective dose CCs were evaluated in two irradiation geometries, AP and PA. In each projection, it was used10^6 histories. The number of histories used on the simulations supply errors below 10% to the values of the calculated. The main values of CCs equivalent dose and effective for the patient and physician are shown in table 1

Table 1. Equivalent and effective dose conversion coefficient normalized for KAP simulated for patient and physician.

Organs/Tissues	**H/PKA**			
	Patient mSv/Gycm²		**Physician** µSv/Gycm²	
	AP	**PA**	**AP**	**PA**
Heart	4.328	0.243	0.358	0.041
Muscle	1.987	4.266	0.100	0.004
Kidneys	0.043	0.001	0.070	0.001
Small Intestine	0.346	0.001	0.165	0.003
Thymus	0.004	0.033	0.325	0.002
Spleen	0.200	0.018	0.165	0.002
Pancreas	6.712	0.002	0.231	0.003
Adrenal	0.185	0.002	0.069	0.001
Skin	8.227	8.094	0.239	0.011
Liver	1.671	0.005	0.273	0.004
Esophagus	0.058	0.077	0.160	0.001
Thyroid	0.727	0.003	0.686	0.005
Colon	8.031	0.028	0.213	0.004
Stomach	21.79	0.005	0.369	0.005
Bone Marrow	0.005	0.916	0.072	0.001
Breasts	1.329	0.100	2.493	0023
E/PKA	**5.210**	**0.795**	**3.680**	**0.048**

Considering the tension on the used tube in this study (70 kV), the equivalent dose (H) was estimated by the kerma approximation, in other words, the energy deposition by electrons occurred in the interaction site. In this sense, it was considered that the absorbed dose by each organ/tissue was equal to the equivalent dose contained in itself, because, for photons the weighting factor (w_r) is equal to the unity [13].

As expected, the dose values in the patient organs are significantly superior to the physician dose values. CCs variations among the organs studied could be related to the differences in localization, depth and size of the organs. During coronary angiography procedure, the projection PA is the most commonly used. In this projection, the physician and patient had lower conversion coefficient of equivalent dose and effective.

4. CONCLUSION

This study estimated the absorbed doses in organs and tissues of patients and physician coronary angiography procedure. Through simulated doses, it was possible to determine the conversion coefficients of effective dose and equivalent dose of two irradiation geometries (AP and PA). Since these conversion coefficients are known, it is possible to estimate radiation protection dosimetric quantities, as effective dose and equivalent dose. The estimative is made through the product of CCs obtained with the KAP measured in X-ray equipment. The conversion coefficients obtained in this study can be useful in assessing the possible damage caused by radiation-induced effects in patients and physicians who routinely work in coronary angiography procedures.

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